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TOMATO DISEASES IN CALIFORNIA

By RALPH E. SMITH.

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OF MYCOLOGY

Blighted tomatoes in re-budded lemon orchard.

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TOMATO DISEASES IN CALIFORNIA.

By RALPH E. SMITH.

Among the losses caused by plant diseases in California during the past season, those of the tomato grower have been among the most serious. In every section of the State where the crop is extensively grown much loss was occasioned all through the season by tomato "blight," and some growers have become considerably discouraged at the outlook for this crop. The present bulletin contains the results of no very extended investigation of the subject, but is to be considered rather as a preliminary report; the growers are so entirely in the dark as to the cause, nature, and possible means of prevention of these troubles that a publication of what is known upon the subject seems justified at this time. Further investigation is in progress, particularly as a part of the work of the new pathological laboratory for southern California.

TOMATO GROWING IN CALIFORNIA.

Canning Crop.—Tomatoes are grown largely in the State for canning, and for this purpose are usually planted to mature in late summer and fall, coming to the cannery after the fruit season is over and finishing the year's run. This may be called the main crop, and is grown largely in Alameda and Santa Clara counties, in the San Joaquin and lower Sacramento valleys, and in southern California.

Winter Crop.—Very recently there has developed in certain practically frostless sections of southern California, a profitable shipping trade in fall and winter tomatoes, the vines commencing to bear after the beginning of cold weather in the East, and continuing well into the winter without protection. In the usually dry, warm weather previous to December 1st a large amount of fruit will set on the vines, and it has been found that such fruit, maturing abundantly in October, November, and December or later, may be shipped East when the market is practically bare, and command a ready and profitable sale. This fruit is picked in a hard-ripe condition, carefully selected, wrapped in paper, and shipped in four-box crates like plums or peaches. During the past fall nearly 500 acres of these winter tomatoes were grown in the La Habra district, near Whittier, mostly in young walnut orchards, and more in other sections about Los Angeles. With the canners paying about $8 per ton for the summer crop, the rates of $30 to $50 realized

from winter tomatoes look very attractive and make the business profitable to the grower. The production is large and of good quality. Altogether the growing of winter tomatoes in suitable localities may be called a promising industry, capable of considerable further development.

Early Crop.—In early spring tomatoes are planted by vegetable growers in many parts of the State, and these supply the local markets in the earlier part of the season. This business usually brings good returns, though the production is not so large as in the later crops.

DISEASES.

The tomato in California has had but few serious troubles. The fruit is not disposed to decay, and the vine grows with extreme vigor, except when attacked by the diseases which form the subject of this bulletin. These may now be taken up in detail.

DAMPING-OFF.

Millions of tomato plants are lost some years in the seed-bed by "damping-off," or stem rot of the seedlings. This trouble, and the conditions which favor it, are well known to most growers. During periods of wet, continued cloudy weather in spring, the disease occurs. The little plants growing close together wilt down on the soil, and die off in patches or in whole beds. If examined more closely it will be seen that each plant is affected with a soft rot just at the surface of the ground, which cuts it off and causes its death.

Cause.—The cause of damping-off is a mold-like fungus, not always the same, which lives in the soil and does not always develop enough to affect healthy plants. The conditions mentioned of close, wet weather, with little sunshine for some time, favor the fungus and weaken the plant. Thus the former gets the upper hand, develops very vigorously in the soil, and penetrates into the stem of the weakened, delicate seedling. This produces a decay, the stem rots off, and the fungus spreads rapidly over the soil from plant to plant, until a large area may be killed, if favorable conditions continue. When the sun begins to shine again and the soil is thereby dried off and the young plants invigorated, damping-off is checked and disappears.

Control.—It should be kept in mind, in considering how damping-off may be prevented or checked, that the trouble is caused by a soil fungus which is favored by moisture, cloudy weather, weak plants, and any condition which produces the same effects, while its growth is hindered by dryness and anything which produces it, like sunshine and ventilation. Seed-beds should be made of fresh soil, free from anything con-

nected with previous crops of tomatoes. The seed should not be planted too thickly, as a close, dense growth of the plants greatly favors damping-off. After the seedlings appear, the surface of the ground should be kept as dry as possible by stirring, covering the beds during rain, opening to let in all possible sun and wind, and watering as little as possible.

At times when the weather is bad the plants will sometimes commence dying in spite of all these precautions. At such times it is difficult to stop the spread of the trouble by any treatment. Some growers have sprinkled sulfur thickly over the young plants, and report some success in checking the disease. A sprinkling of air-slaked lime may also have a beneficial effect by drying and covering the surface of the soil. Further treatment consists in spraying the plants and soil heavily with a weak Bordeaux mixture (3 pounds of lime, 3 pounds of bluestone, and 50 gallons of water), in order to check the spread of the fungus over the surface of the soil. Such a spraying, combined with a sprinkling of dry sulfur, will check damping-off, as much as can be done by any means at times of continuous dull weather with conditions favorable to the disease. If a bed becomes badly affected, it is better to let it go altogether and start new plants in fresh soil.

Soil sterilization by means of steam for the purpose of exterminating soil fungi has never been attempted in California, but is being practiced quite extensively in certain Eastern sections for hot-houses, cold frames, etc. The method is simple, and kills every form of parasitic or other life in the soil treated. Perforated pipe or tile is placed in the soil in a gridiron arrangement, buried to a depth of about a foot, and steam then turned in from a boiler and kept up for some time. The soil becomes permeated with the hot steam and all fungus spores, weed seeds, insects and their eggs, etc., are destroyed. The growth of plants in soil after such treatment is also considerably stimulated. For large growers of tomato or other plants who are losing seriously by damping-off, this method is worth considering. The writer will be pleased to give further details to any one interested in the subject.

SUMMER BLIGHT.

Under the term "blight" is commonly designated in California a tomato disease which is known everywhere in the State in greater or less abundance, and occurs not infrequently as the cause of losses up to 100 per cent of plants between half-grown and maturity. This is here termed the "summer blight," to distinguish it from another disease to be described later. The disease seems to have been known longest in its severe form in the San Joaquin Valley. Losses of entire fields of good-sized plants have been known there for several years, and in fact this has come to be almost the rule in that section. In Alameda and

Santa Clara counties the disease has frequently been seen on occasional plants, but has not been considered as of any serious importance. In southern California this blight has been the cause of considerable loss in recent years. In 1905 the disease was probably more general than ever before, completely ruining many fields in southern California, almost all in the San Joaquin, and causing a loss of from 1 to 50 per cent of the plants in fields all over the State.

The principal effects of this disease are seen in the main or canning crop of tomatoes grown in summer, and in the last of the early crop.

FIG. 1. Tomato plant affected by Summer Blight.

The plants, after being set out, usually reach considerable size, blossoming and setting fruit before showing the disease. It first appears here and there in the field on single plants, which begin to fall behind the others in growth, grow somewhat spindling and generally sickly looking, and gradually turn to a dull, unhealthy color and begin to wilt. The leaves do not blacken or suddenly die, but the whole plant gradually sickens, wilts, fades away, and finally collapses upon the ground and becomes entirely dead. The disease comes on gradually in the field, affecting plants here and there in a very scattering manner. In the worst cases they all die before the summer is over, and sometimes all quite suddenly at the last; again, the field goes through in a

spotted condition, with plants missing more or less extensively. If a badly affected or dead plant be pulled up, the roots are found to be decayed or destroyed. When first affected this is not the case; if a plant is pulled up as soon as it begins to show wilting and fading, the roots look healthy and sound. But if such plants be carefully dug, to avoid breaking off the smaller roots, it will be seen that many of the larger

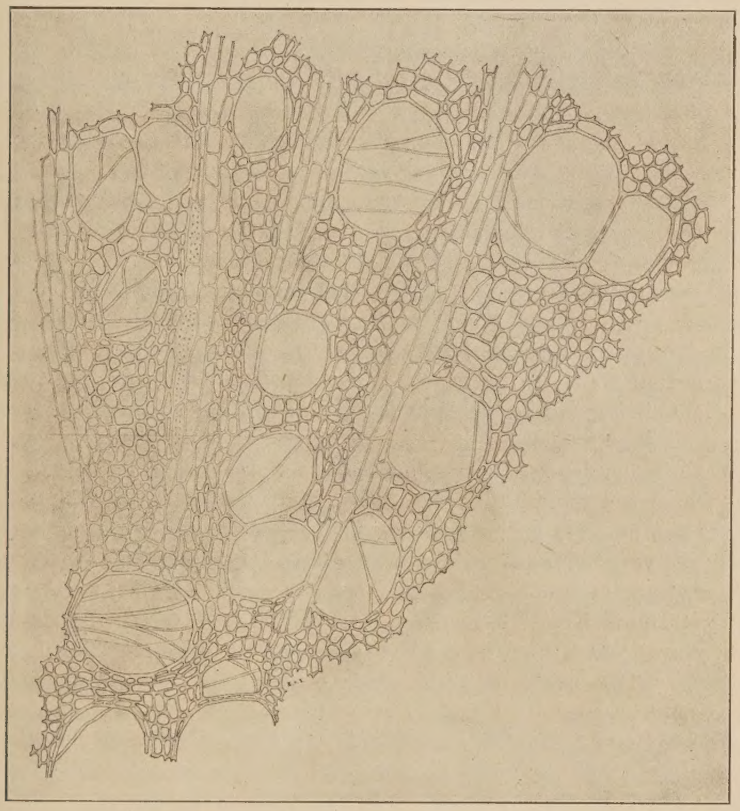

FIG. 2. Cross-section of Tomato root, showing woody portion with *Fusarium* fungus in large water ducts.

laterals are decayed at the ends and in bad condition. These parts are broken off, and very likely are not noticed if the plant is pulled out of the ground by force. By careful digging any plant which shows the symptoms of the disease at all can be seen to be affected in the manner of a dry rot of the roots, commencing at the ends and working up.

Cause.—This trouble has been commonly referred to as the bacterial blight, an Eastern tomato disease. It is not that disease, however, nor has the latter, so far as the writer is aware, ever been found in this

State. The effect is somewhat similar, though not decidedly so. In the California disease the decayed roots show at all times a typical root-rot fungus of the *Fusarium* type. Fungi of this sort live in the soil and cause root or stem rot diseases of a great variety of plants. The fungus grows into the roots and flourishes particularly in the large water-conveying ducts of the central portion. These become filled with the fungous growth and the supply of water is cut off from the plant above. (See Fig. 2.) The present disease is now under investigation by this department, particularly as to the identity of the *Fusarium*, and the manner of infection of the plant. Affected plants obtained last season from Yuba City, Fresno, Merced, Niles, Milpitas, Los Angeles, and Whittier showed in all cases a disease apparently the same. The root decay seemed always to begin at the ends of the smaller roots, at a considerable depth in the soil, gradually working up into the tap-root. The plant above ground remains free from the fungus, simply wilting and dying from starvation and lack of water. How the fungus spreads and in what manner plants first become infected are questions which must be determined before any definite method of prevention can be suggested. Growers state that the disease occurs abundantly in plants started in new soil and planted in new land. It is hoped to determine this and other important points during the coming season.

A *Fusarium* disease of watermelon is very prevalent in some localities where the tomato trouble occurs, but whether the two have any connection has not yet been determined. There also appears to be at least one very common species of *Fusarium* indigenous to our soil.* In the *Fusarium* disease of the garden aster described by the writer in 1901 (Bulletin No. 79, Massachusetts Experiment Station) it was found that plants which died in the field were only those which had become infected in the seed-bed, while healthy plants did not get the disease after being set out in the field. In this case the *Fusarium* caused a damping-off of the seedlings. The latter is also apparently true with tomatoes, though the matter has not yet been thoroughly investigated. The California tomato disease appears somewhat different from the "Sleeping Disease" or wilt, described as being caused by *Fusarium lycopersici* Sacc., being strictly a root rot, confined to the soil.

Control.—Pending further investigation of this disease, little can be said concerning methods for its control. Great care should be taken to make the seed-bed of absolutely new material, and to plant the field where the disease has not occurred. Spraying the tops is perfectly useless, since the trouble is entirely below ground. Experimental plantings are planned for this year, on infected and new soil, both in

*Mr. C. O. Smith, a graduate student of the College of Agriculture of the University, is at present engaged in a study of all the *Fusaria* occurring in the State.

the seed-bed and field, and on sterilized soil. Methods of soil treatment will also be considered. The matter of resistant varieties is also worthy of some attention, particularly in selecting seed from resistant plants in fields where the disease is abundant.

WINTER BLIGHT.

During the past fall a disease of an entirely different nature from that just described has come upon the winter tomato fields of the La Habra and other southern districts, and completely ruined them. In the district mentioned the shipments fell off within a very short time from 3,000 crates per day to practically nothing, and at a time when an increase should have been taking place. Many thousands of dollars were lost to the growers from this cutting-off of the crop just at the most profitable season. The disease which brought about this result may be designated by the above name according to the season of its occurrence, to distinguish it from the summer disease or blight. It may be said here that the *Fusarium* disease does not seem to continue into the fall, the late crops showing very little of this trouble.

After the recent heavy November rains in southern California, tomato picking and shipping were just approaching the height of the season. The vines were covered with green fruit, good returns had already been made, and an excellent prospect was in sight. Quite suddenly, however, in the early part of December or last of November, this winter blight appeared and ruined the crop. The period was one of warm days and cold nights, following heavy rain. The disease appeared quite differently from the former blight. There was no wilting or gradual dying of the vines, but there first appeared dark, discolored spots on the fruit, stems, branches, and leaves. On the fruit (Fig. 3) a discolored, watery spot develops, usually on the upper side, and therefore mostly near the stem end. This increases quite rapidly, several spots appear on one tomato, and it soon rots and is spoiled. Fruit of all sizes is affected, from the smallest to that ready to pick. When sound-appearing fruit is picked from affected vines, many of the tomatoes develop the spots and rot in the box within a few days. In moist weather a white, mildew-like mold comes out abundantly on the affected spots. On the stems and branches dark spots appear (Fig. 4), and soon the whole vine becomes black and dead, with green tufts remaining here and there, exactly as though the field had been struck by frost. In many cases this blight was mistaken for the effects of frost, when no frost had occurred. In blighted fields the ground remained covered with tomatoes, all spotted, infected with rot, and worthless.

Cause.—This trouble proved to be a common disease of another plant which sometimes attacks the tomato, but very seldom as seriously as this. It is the *potato blight* or mildew, well known to every Eastern

potato-grower as the cause of great losses in potatoes, both as a blight of the tops and rotting of the tubers. The cause is a parasitic fungus

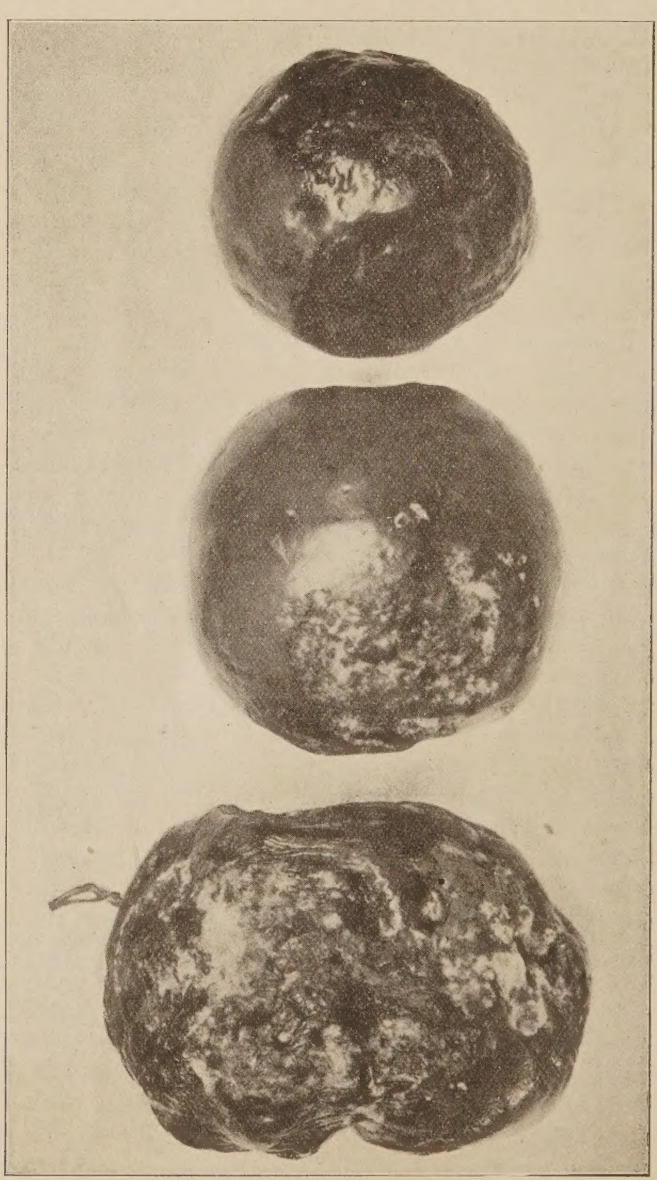

FIG. 3. Tomatoes spotted and decayed by *Phytophthora*, or Winter Blight.

(*Phytophthora infestans* D.By.), and this same fungus was the cause of the winter blight of the tomato. It is a disease which is greatly favored

by wet weather, and for that reason attacked the tomatoes when it did, but such a destructive effect in this crop is quite unusual. There seems,

FIG. 4. Tomato branch affected by *Phytophthora*.

indeed, to be no case recorded where *Phytophthora* has affected the tomato to such an extent as this. The fungus is identical in every way

with that of the potato, showing the characteristic swellings of the conidiophores, and growing readily on the cut surface of potatoes.

FIG. 5. Field of tomatoes in young walnut orchard, with vines killed by *Phytophthora*.

The white mildew seen on the surface of affected tomatoes is the fungus which is responsible for the disease. It consists of fine, branch-

ing threads which grow into the fruit and branches, producing the rotting and discoloration. (Fig. 6.) The filaments also grow out on the surface in moist air, and on the tips of these aërial filaments, the sporangiophores, are produced the egg-shaped spores of the fungus. (Fig. 7.) These soon drop off and are scattered by the wind in all directions. Their further development is somewhat peculiar. Instead

FIG. 6. Tissue of tomato, with filaments of *Phytophthora*.

of simply sprouting and forming new filament threads like most spores, the contents of each one divide inside into a number of smaller spores, called *swarm-spores*. The original spore, or *sporangium*, then opens at the end and the little swarm-spores flow out. Each one is provided on the side with two fine cilia, or tail-like appendages. By means of these they are able to swim vigorously about in drops of rain water, dew, or any moisture, so that by the wind blowing the sporangia, which themselves are only about one one-thousandth of an inch in diameter, and

the swimming of the swarm-spores, the disease is able to spread rapidly in wet weather. (Fig. 8.) The swarm-spores finally come to rest, sprout,

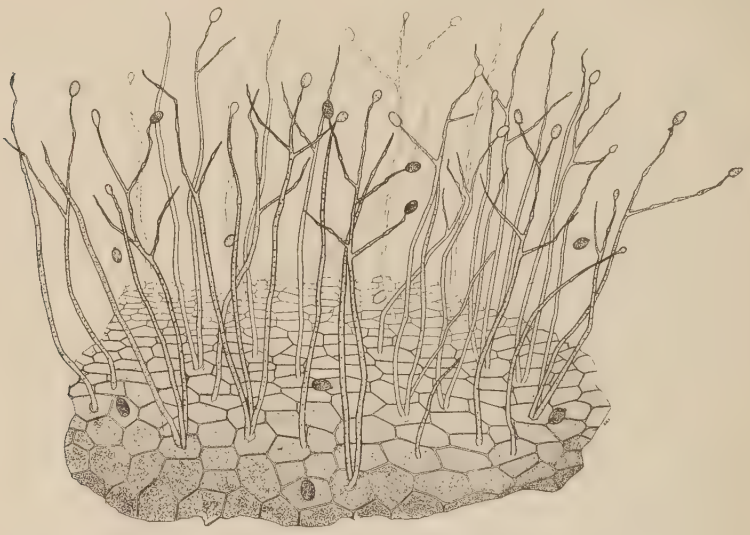

FIG. 7. Surface growth of *Phytophthora* on tomato, showing formation of sporangia.

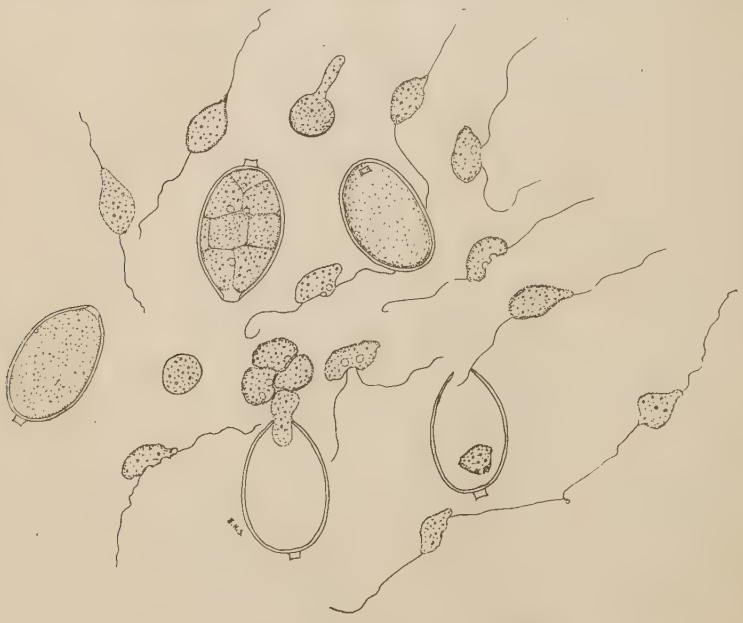

FIG. 8. Formation of swarm-spores of *Phytophthora*.

and if situated on a potato or tomato plant the filaments grow into the tissue, a new black spot appears, and the blight increases.

In dry weather this disease is not to be feared, as it can only develop with an abundance of moisture. For this reason it is comparatively rare on potatoes in California, only occurring occasionally in sections or seasons with a great deal of rain or very heavy dews. Potato blight is not uncommon in the coast section of Monterey County, and occurred extensively about Sacramento on the fall crop of 1904 and the spring crop of 1905, both being seasons of a large amount of rain. The group of fungi to which *Phytophthora* belongs, the *Peronosporeæ*, all show the same moisture requirement and are comparatively rare in California. The downy mildew of the grape (*Plasmopara viticola* Berk.) is particularly conspicuous by its absence. The onion mildew (*Peronospora schleideni* Ung.) becomes abundant and troublesome in our great seed fields only in unusually wet seasons. The relation of the *Phytophthora*, or winter blight, to the tomato crop is therefore very positively one of moisture, and the disease need not be feared or considered at all in the summer crop, or at any time except when there is much moisture in the air from continuous heavy fog or rain.

Treatment.—The control of this disease has been thoroughly worked out in Eastern States for potatoes, and the same methods will no doubt prove effective here. Treatment consists in spraying with Bordeaux mixture; in climates with frequent rains in summer this is done several times at regular intervals, in order to keep the vines well covered with spray at all times. In California this would not be necessary. Spraying should be regulated entirely by the rainfall. If there is no rain there is no danger whatever of winter blight, and no need of spraying.

If rains occur while the vines are in growing or bearing condition, spray thoroughly with Bordeaux mixture immediately after the rain stops. If there should be frequent showers a day or a few days apart, spray between showers rather than wait too long. Aim to cover the fruit and all parts of the vine with the spray. If the mixture shows on the fruit when picked, it can be easily wiped off. Bordeaux mixture is not poisonous. Repeat the spraying after the next rain, if any occurs; but continued spraying in dry weather is not necessary. One good spraying at the right time last fall would probably have saved thousands of dollars in the winter tomato crop.

It is advisable, in regard to this disease on general principles, not to plant tomatoes on the same land one year after another, although the *Phytophthora* spreads so rapidly when conditions are favorable that this precaution could have little effect in preventing the blight.

SUMMARY.

Three serious tomato diseases occur in California.

"*Damping-Off*" is a stem rot of the young plants in the seed-bed, which occurs mostly in wet, cloudy weather or in seed-beds which are

over watered or poorly ventilated. It is caused by a fungus or various fungi which spread on the surface of the ground under such conditions and kill the young plants. To prevent this trouble it is necessary to use fresh earth in the seed-bed, keep the soil dry on top, ventilate the beds well, and avoid overcrowding the plants. To check the disease when started, spraying the soil and plants with weak Bordeaux mixture, followed by a sprinkling of sulfur, is recommended. A trial of soil sterilization by means of steam is suggested to large growers.

"*Summer Blight*" is a wilt and gradual dying of mature or partly grown plants in the field, which occurs extensively in the San Joaquin Valley and southern California, and somewhat in the San Francisco Bay region, mostly in the summer crop. The disease is caused by a species of *Fusarium*, a soil fungus, which causes a dry rot of the roots and cuts off the supply of soil water from the plant. This disease forms one of the present subjects of investigation by this department. At present the only recommendations which can be made consist in taking great pains to obtain healthy plants, and planting in new soil. Applications of lime, sulfur, etc., to the soil may be tried by the grower, but the effect of such treatment has not yet been demonstrated. Spraying can not be of any use with this disease.

"*Winter Blight*" is a disease caused by the potato-blight fungus, *Phytophthora infestans*, which, under favorable conditions, has seriously affected winter tomatoes in southern California. The same trouble was observed on potatoes in Sacramento County in the fall of 1904 and spring of 1905, and in the coast region of Monterey County, but is not very prevalent in California. This fungus causes a spotting of green and ripe tomatoes, dark spots on the stems and branches, and complete and sudden ruin of the crop. It occurs only after heavy rains or very heavy fogs and dews, and consequently affects only the winter crop of tomatoes. Such plantings should be sprayed heavily with Bordeaux mixture after every rain to prevent the development of this form of blight.

DIRECTIONS FOR PREPARING BORDEAUX MIXTURE.

Bluestone	**5 lbs.**
Quicklime	**5 lbs.**
Water	**50 gals.**

Dissolve the bluestone and slake the lime in separate barrels. Dilute the bluestone with half or more of the water, then strain in the lime mixed with the remainder of the 50 gallons of water. Use while freshly prepared.

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